

Judul Disertasi

PAJANAN RADIASI GELOMBANG ELEKTROMAGNETIK RADIO FREKUENSI TELEPON SELULER TERHADAP KUALITAS DAN FUNGSIONALITAS SPERMATOZOA MANUSIA (Kajian *in vitro* Konsentrasi, Motilitas, Morfologi, Apoptosis, Kalsium Intraseluler dan Ekspresi *Voltage-Gated Calcium Channel* Spermatozoa)

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Pendahuluan. Telepon selular (ponsel) adalah bagian penting dalam kehidupan manusia modern, dan diperlukan penelitian untuk mengevaluasi konsekuensi dari meningkatnya penggunaan *smartphone*.

Tujuan Penelitian. Penelitian ini bertujuan untuk mengungkapkan dampak pajanan radiasi gelombang elektromagnetik radiofrekuensi ponsel terhadap perubahan kualitas dan fungsionalitas spermatozoa dan untuk mengetahui mekanisme adanya hambatan ekspresi *Voltage-Gated Calcium Channel* (VGCC) spermatozoa sebagai perubahan pada tingkat molekuler akibat pajanan radiasi ponsel yang menyebabkan infertilitas pada pria.

Metode. Jenis penelitian adalah Eksperimental laboratorik dengan rancangan *pre-post test controlled group design*. Subyek penelitian adalah spermatozoa manusia dengan kualitas sesuai kriteria WHO (1999). Variabel bebas adalah pajanan radiasi gelombang elektromagnetik radiofrekuensi ponsel diukur dengan *electromagnetic radiation detection*, variabel terikat adalah kualitas (konsentrasi, motilitas, morfologi) spermatozoa diperiksa secara konvensional sesuai panduan WHO (1999), dan fungsionalitas spermatozoa berupa apoptosis dan Ca intraseluler dengan *flowcytometry* serta ekspresi *Voltage-Gated Calcium Channel* (VGCC) diperiksa secara *immunocytochemistry*. Data hasil pemeriksaan diuji menggunakan analisis *Kruskall-Wallis* dan uji post hoc dengan *Mann Whitney* serta *Pearson correlation test* untuk mengetahui kekuatan hubungan dua variabel.

Hasil. Penelitian ini menyatakan bahwa semakin lama (1 jam dan 2 jam) serta besar pajanan (SAR 2 W/kg dan 5.7 W/kg) radiasi gelombang elektromagnetik radiofrekuensi ponsel, semakin rendah kualitas spermatozoa yaitu konsentrasi spermatozoa ($p < 0.05$), motilitas ($p < 0.05$), morfologi ($p < 0.05$) dan fungsionalitas spermatozoa yaitu apoptosis ($p < 0.05$), jumlah kalsium intraseluler ($p < 0.05$) dibanding kelompok kontrol. Ada hubungan antara ekspresi *Voltage-Gated Calcium Channel* (VGCC) pada spermatozoa dengan kualitas spermatozoa (konsentrasi spermatozoa $p = 0.003$; $r = 0.361$; motilitas B $p = 0.000$; $r = 0.664$; motilitas D $p = 0.000$, $r = -0.660$; morfologi normal $p = 0.000$; $r = 0.634$; morfologi kelainan ekor $p = 0.008$, $r = -0.324$) dan fungsionalitas spermatozoa (apoptosis $p = 0.039$; $r = 0.257$) setelah terpajan radiasi gelombang elektromagnetik radiofrekuensi ponsel.

Simpulan dan Saran. Semakin lama (akut dan kronik) dan besar pajanan (SAR 2 W/kg dan 5.7 W/kg) radiasi gelombang elektromagnetik radiofrekuensi ponsel, semakin rendah kualitas (konsentrasi, motilitas, morfologi) dan fungsionalitas (apoptosis, jumlah kalsium intraseluler) spermatozoa manusia. Semakin sedikit ekspresi VGCC di dapat berarti semakin sedikit kanal kalsium yang bersifat terbuka, sehingga semakin rendah kualitas dan fungsionalitas spermatozoa. Pajanan radiasi ponsel mempengaruhi ekspresi *Voltage-Gated*

Calcium Channel (VGCC) pada spermatozoa. Dampak radiasi gelombang elektromagnetik radiofrekuensi ponsel dapat dicegah. [Kata kunci :*in vitro*, radiasi ponsel, kualitas, fungsionalitas, spermatozoa.]

ELECTROMAGNETIC WAVE RADIOFREQUENCY RADIATION EXPOSURE OF CELL PHONE ON QUALITY AND FUNCTIONALITY OF HUMAN SPERMATOZOA (*in vitro* Studies of the Effects of cell phone on the Concentration, Motility, Morphology, Apoptosis, and Expression of Intracellular Calcium, Voltage-Gated Calcium Channel of Spermatozoa)

Background. Cell phone is an essential part of every human modern life, and research is needed to evaluate the consequences of the increasing use of smartphones.

Research Objective. This study aims to reveal the impact of radiofrequency electromagnetic wave radiation exposure of cell phones on the changes the quality and functionalities of spermatozoa and to determine the mechanism of the barriers to the expression of Voltage-Gated Calcium Channel (VGCC) spermatozoa as changes at the molecular level due to exposure to cell phone radiation which results in infertility in men.

Research Methodology. The type of this research design is the laboratoric experimental pre - post test controlled group design. The subjects of the research is the quality of sperm according to WHO (1999) criteria. The independent variable was exposure to radiofrequency electromagnetic waves mobile phone radiation measured with an electromagnetic radiation detection. The dependent variable is the quality (concentration, motility, morphology) of spermatozoa conventionally examined according to WHO guidelines (1999), and functionality of spermatozoa in the form of expression of Voltage-Gated Calcium Channel (VGCC) examined by immunocytochemistry and apoptosis and intracellular Ca^{2+} measured with flowcytometry. Data were analyzed using Kruskal Wallis and post hoc with Mann Whitney and Pearson correlation tests.

Results. This study suggests that the longer (1 hour and 2 hours) and large exposures (SAR 2 W/kg and 5.7 W/kg) radiation is electromagnetic wave radiofrequency cell phone, the lower the quality of the sperm is sperm concentration ($p < 0.05$), motility ($p < 0.05$), morphology ($p < 0.05$) and the functionality of spermatozoa that apoptosis ($p < 0.05$), the amount of intracellular calcium ($p < 0.05$) than the control group. There is a relationship between the expression of Voltage-Gated Calcium Channel (VGCC) on spermatozoa with the quality of spermatozoa (concentration spermatozoa $p = 0.003$; $r = 0.361$; motility B $p = 0.000$; $r = 0.664$; motility D $p = 0.000$, $r = -0.660$; morphology normal $p = 0.000$; $r = 0.634$; morphological abnormalities tailed $p = 0.008$, $r = -0.324$) and the functionality of spermatozoa (apoptosis $p = 0.039$; $r = 0.257$) following exposure to radiofrequency electromagnetic radiation of cell phones.

Conclusion and Suggestion. The longer (acute and chronic) and large exposures (SAR 2 W/kg and 5.7 W/kg) of cell phone radiofrequency is electromagnetic wave radiation, the lower the quality (concentration, motility, morphology) and functionality (apoptosis, the amount of intracellular calcium) of human spermatozoa. The less expression in the VGCC can mean less calcium channels that are open, so the lower the quality and functionality of spermatozoa. Exposure to cell phone radiation affects the expression of Voltage-Gated Calcium Channel (VGCC) on spermatozoa. The impact of cell phone radiofrequency electromagnetic wave radiation can be prevented. [Keywords : *in vitro*, cell phone radiation, quality, functionality, human sperm.]